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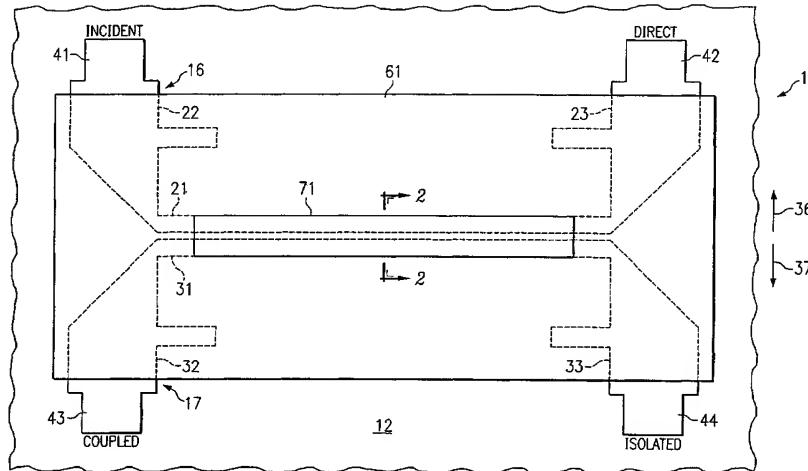
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**Declarations under Rule 4.17:**

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for all designations
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations

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(54) Title: DEVICE FOR DIRECTING ENERGY, AND A METHOD OF MAKING SAME



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(57) Abstract: A hybrid coupler (10, 90, 110, 130, 160, 210) includes a substrate (12) having a coupling structure formed thereon using thick film processing techniques. The coupling structure includes two parallel conductive strips (21, 31). One strip (21) is coupled at one end to an incident port (22) and at the other end to a direct port (23). The other strip (31) is coupled at one end to a coupled port (32) and at the other end to an isolated port (33). An electrically conductive shield (71, 91, 111, 164) is aligned with and enhances coupling between the conductive strips. A dielectric layer (61, 162) is provided between the shield and the conductive strips.



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DEVICE FOR DIRECTING ENERGY,  
AND A METHOD OF MAKING SAME

TECHNICAL FIELD OF THE INVENTION

This invention relates in general to devices for directing energy and, more particularly, to a hybrid coupler which is part of an integrated circuit and which is capable of directing microwaves or other energy.

BACKGROUND OF THE INVENTION

Passive power couplers are a fundamental type of integrated circuit device used in many high frequency signal processing systems, such as microwave systems. Applications include balanced mixers, balanced amplifiers, phase shifters, attenuators, modulators, discriminators, and measurement bridges. An ideal hybrid coupler is a junction having four ports, which are commonly known as the incident port, the direct port, the coupled port, and the isolated port. Energy of a wave applied to the incident port is supplied to each of the direct port and the coupled port, but not to the isolated port. The amount of the input energy coupled to each of the direct and coupled ports may be about the same, or may differ according to some selected proportion.

In recent years, there has been a significant increase in the typical operating frequencies of leading edge systems which use these hybrid couplers. In particular, typical operating frequencies have increased by factors in the range of 3 to 6, for example from a typical frequency of about 3 GHz to a typical frequency in the range of about 10-18 GHz. As these frequencies

have increased, it has been necessary for the size of the couplers to decrease. As a result, a broadband microwave hybrid coupler typically requires small dimensions within the coupled structure, in order to achieve tight coupling across a relatively wide frequency range. These small dimensions are commonly achieved using known types of opto-lithographic techniques, which are commonly referred to in the art as thin film technology. While couplers made with thin film technology have been generally adequate for their intended purposes, they have not been satisfactory in all respects.

One aspect of this is that the fabrication of couplers using thin film technology involves an undesirably high cost. One less expensive fabrication technique used for other types of integrated circuits involves screen printing techniques rather than opto-lithographic techniques, and is commonly known in the art as thick film processing. However, while thick film technology is generally cheaper, the fabrication tolerances are looser for thick film technology than for thin film technology. Consequently, because small and accurate dimensions have been needed in pre-existing high-frequency coupler designs, the industry has generally considered it impractical to implement hybrid couplers using thick film techniques, especially for high-frequency applications such as microwave systems.

#### SUMMARY OF THE INVENTION

From the foregoing, it may be appreciated that a need has arisen for a hybrid coupler which can be made by thick film techniques, with good production yields and with good performance characteristics. According to one

form of the present invention, an apparatus is provided to address this need, and involves a coupler which includes: a thick film dielectric layer having first and second sides; a thick film first strip made of an electrically conductive material and disposed on the first side of the dielectric layer; a thick film second strip made of an electrically conductive material and disposed on the first side of the dielectric layer, the first and second strips extending approximately parallel to each other; and a thick film shield made of an electrically conductive material and disposed on the second side of the dielectric layer in alignment with the first and second strips.

According to a different form of the present invention, a method of making a coupler involves: forming a dielectric layer using a thick film technique, the dielectric layer having first and second sides; forming a first strip which is electrically conductive using a thick film technique, the first strip being disposed on the first side of the dielectric layer; forming a second strip which is electrically conductive using a thick film technique, the second strip being disposed on the first side of the dielectric layer, and the first and second strips extending approximately parallel to each other; and forming a shield which is electrically conductive using a thick film technique, the shield being disposed on the second side of the dielectric layer in alignment with the first and second strips.

#### BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention will be realized from the detailed description which follows,

taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a diagrammatic fragmentary top view of an integrated circuit with a coupler which embodies the present invention;

FIGURE 2 is a diagrammatic fragmentary sectional view taken along the section line 2-2 in FIGURE 1;

FIGURE 3 is a diagrammatic fragmentary sectional view similar to FIGURE 2, but showing a coupler which is an alternative embodiment of the coupler of FIGURE 2;

FIGURE 4 is a diagrammatic fragmentary sectional view similar to FIGURE 2, but showing a coupler which is yet another alternative embodiment of the coupler of FIGURE 2;

FIGURE 5 is a diagrammatic fragmentary sectional view similar to FIGURE 2, but showing a coupler which is still another alternative embodiment of the coupler of FIGURE 2;

FIGURE 6 is a diagrammatic fragmentary sectional view similar to FIGURE 5, but showing a coupler which is an alternative embodiment of the coupler of FIGURE 5; and

FIGURE 7 is a diagrammatic fragmentary top view similar to FIGURE 1, but showing an integrated circuit with a coupler which is yet another alternative embodiment of the coupler of FIGURE 1.

#### DETAILED DESCRIPTION OF THE INVENTION

In order to more clearly convey an understanding of the present invention, certain features in the drawings are not shown to scale. With this in mind, FIGURE 1 is a diagrammatic fragmentary top view of an apparatus which is part of an integrated circuit that implements a hybrid

coupler 10, where the coupler 10 embodies aspects of the present invention. FIGURE 2 is a diagrammatic fragmentary sectional view taken along the section line 2-2 in FIGURE 1. The coupler 10 includes a substrate 12, which in the disclosed embodiment is alumina. However, the substrate 12 could alternatively be made of some other suitable material, such as aluminum nitride or beryllium oxide. The substrate 12 has on the underside thereof a not-illustrated ground plane of a standard type, in order to facilitate operation of microstrip structure which is described below.

More specifically, two separate electrically conductive sections 16 and 17 are formed top of the substrate 12. The conductive sections 16 and 17 are each formed by thick film techniques of a type known in the art, which involve screen-printing the conductive sections 16 and 17 onto the substrate 12. The conductive sections 16 and 17 each have a thickness of approximately 300 microns, but could alternatively have some other suitable thickness which is compatible with formation by thick film techniques. In the disclosed embodiment, the conductive sections 16 and 17 are each made of gold, but could alternatively be made of some other suitable material which is electrically conductive, such as a different type of metal.

The conductive section 16 includes an elongate strip 21, an incident port 22 at one end of the strip 21, and a direct port 23 at the other end of the strip 21. The strip 21 and the ports 22-23 are respective integral portions of the conductive section 16. In a similar manner, the conductive section 17 includes an elongate strip 31, a coupled port 32 at one end of the strip 31,

and an isolated port 33 at the other end of the strip 31. The strip 31 and the ports 32-33 are respective integral portions of the conductive section 17. The strip 31 is spaced a small distance from and extends parallel to the strip 21, such that the adjacent edges of the strips 21 and 31 extend parallel to each other. The strips 21 and 31 serve as a pair of microstrip coupled lines.

The ports 22 and 23 extend from respective ends of the strip 21 in a direction away from the strip 31, and thus extend approximately in a direction 36 which is transverse to the strips 21 and 31. The ports 32 and 33 extend from respective ends of the strip 31 in a direction away from the strip 21, and thus extend approximately in a direction 37 which is transverse to the strips 21 and 31, and which is opposite to the transverse direction 36. The ports 22, 23, 32 and 33 each have at the outer end thereof a respective portion 41-44, which serves as a terminal or pad to which external electrical connections can be made.

With reference to FIGURE 2, the strips 21 and 31 have respective widths 46 and 47. In the disclosed embodiment, the widths 46 and 47 are approximately equal, and are each about 0.004 inches. The lateral spacing or gap 48 between the strips 21 and 31 is approximately 0.002 inches in the disclosed embodiment, but could alternatively be some other suitable dimension.

A layer 61 of a dielectric material is provided over part of the substrate 12, and over the conductive sections 16 and 17, except for the terminals 41-44 at the ends thereof. The dielectric layer 61 is formed using thick film techniques of a known type. In the disclosed embodiment, the dielectric layer 61 has a thickness of

approximately 0.0005 inches, but it could alternatively have some other suitable thickness which is compatible with formation by thick film techniques. As shown in FIGURE 1, the dielectric layer 61 of the disclosed embodiment has an approximately rectangular shape. The terminals 41-44 of the four ports each project transversely outwardly beyond edges of the dielectric layer 61.

In the disclosed embodiment, the dielectric layer 61 is made of a borosilicate glass material which has a dielectric constant of 3.9, and which is commercially available under catalog number KQ125 from Haraeus, Inc. of West Conshohocken, Pennsylvania. However, it could alternatively be made from some other suitable dielectric material.

An electrically conductive shield 71 is formed on top of the dielectric layer 61. The shield 71 is formed using thick film techniques of a known type. In the disclosed embodiment the shield 71 is made of gold, but it could alternatively be made of some other suitable material which is electrically conductive, such as a different metal. The shield 71 in the disclosed embodiment has a thickness of approximately 300 microns, but it could alternatively have some other thickness which is compatible with formation by thick film techniques.

As shown in FIGURE 1, the shield 71 has a shape which is an elongated rectangle. The shield 71 is centered over the conductive strips 21 and 31, and extends almost the entire length thereof. With reference to FIGURE 2, the shield 71 has a width 76 which is approximately equal to the distance 77 between the outer

edges of the strips 21 and 31. However, the shield 71 could have a different width 76, as discussed in more detail later.

As mentioned above, certain aspects of FIGURE 2 are not to scale. As one example, the thickness of the shield 71 and the thicknesses of the strips 21 and 31 are greatly exaggerated in proportion to the thickness of the dielectric layer 61. As a practical matter, it will be recognized that the vertical distance between the shield 71 and the strips 21 and 31 is approximately equal to the thickness of the dielectric layer 61.

During operational use, energy of a wave supplied to the incident port 22 is split between the direct port 23 and the coupled port 32, in a selected proportion which is determined by the design, as discussed later. Ideally, all of the energy from the incident port would be split between the direct port and the coupled port, and none would reach the isolated port 33. As a practical matter, however, a small portion of this energy reaches the isolated port 33.

Due to the fact that the coupler 10 is formed using thick film techniques, the spacing or gap 48 between the conductive strips 21 and 31 is necessarily larger than would be the case if the coupler was made using a thin film technique. This is due to the fact that dimensions and tolerances are more precise with thin film technology than with thick film technology. And since the use of thick film techniques renders the space or gap 48 in the disclosed embodiment larger than would be the case in an embodiment made using thin film techniques, electromagnetic coupling between the conductive strips 21 and 31 would be expected to be somewhat less than for the

conductive strips of a thin film coupler, where the strips could be closer to each other.

In the disclosed embodiment, however, the presence of the shield 71 is effective to significantly increase the level of electromagnetic coupling of energy from the strip 21 to the strip 31, so that the coupling has a suitable level even when the strips 21 and 31 are spaced further apart than would be the case in pre-existing devices. And since the shield 71 permits the gap 48 to be larger than would be practical if the shield 71 was omitted, the larger gap allows a reduction in manufacturing tolerances which avoids the need for thin film technology and instead permits the disclosed coupler to be readily fabricated with low-cost thick film technology. In terms of manufacturing variations, the disclosed coupler 10 permits a fair degree of manufacturing variations with minimal performance degradation. The result is a broadband coupler 10 that can be made with thick film techniques while providing high manufacturing yields.

FIGURE 3 is a diagrammatic fragmentary sectional view of a hybrid coupler 90 which is an alternative embodiment of the coupler 10 of FIGURES 1-2. The coupler 90 is effectively identical to the coupler 10, except that it has a shield 91 with a width 93 which is less than the width 76 of the shield 71 in FIGURES 1-2. Thus, the width 93 of the shield 91 is less than the distance 77 between the outer edges of the conductive strips 21 and 31. Like the shield 71 of FIGURE 2, the shield 91 of FIGURE 3 is formed using thick film techniques, and significantly enhances coupling between the conductive strips 21 and 31, in comparison to a situation where the

shield 91 was omitted. But the shield 91 of FIGURE 3 provides somewhat less coupling than the shield 71 of FIGURE 2, due to the fact that it has a smaller width.

It will thus be recognized that adjusting the width of the shield is a design technique which can be used to set or tune the amount of coupling between the coupling strips 21 and 31, thus adjusting the proportional relationship defining how energy from the incident port 22 is split between the direct port 23 and the coupled port 32. Other design techniques which can be used to adjust the amount of coupling between the strips 21 and 31 involve variation of the gap 48 (FIGURE 2) provided between the conductive strips 21 and 31, variation of the thickness of the dielectric layer 61 that separates the strips 21 and 31 from the shield 71 or 91, and/or use of a different dielectric material with a different dielectric constant for the dielectric layer 61. Varying the widths of the conductive strips 21 and 31 can vary the return loss, and can also have some effect on the degree of coupling between the strips. The length of the conductive strips 21 and 31 can be varied in order to vary the frequency band within which the coupler 10 operates.

FIGURE 4 is a diagrammatic fragmentary sectional view similar to FIGURES 2 and 3, but showing a hybrid coupler 110 which is yet another alternative embodiment of the coupler 10 of FIGURE 2. The coupler 110 is effectively identical to the coupler 10, except that it has a shield 111 with a width 113 which is greater than the width 76 of the shield 71 in FIGURE 2. Consequently, the shield 111 of FIGURE 4 provides a greater degree of coupling between the strips 21 and 31 than the shield 71

of FIGURE 2. The shield 111 is formed using thick film techniques, and is effectively identical to the shield 71 of FIGURES 1-2, except for the fact that the shield 111 is wider than the shield 71.

FIGURE 5 is a diagrammatic fragmentary sectional view of a hybrid coupler 130 which is still another alternative embodiment of the coupler 10 of FIGURE 2. The coupler 130 of FIGURE 5 is effectively identical to the coupler 10 of FIGURE 2, except that the locations of the shield 71 and the conductive strips 21 and 31 have been swapped. In particular, the shield 71 is provided between the substrate 12 and the dielectric layer 61, and the strips 21 and 31 are provided on the upper side of the dielectric layer 61. The shield 71 of FIGURE 5 has the same width and thickness as the shield 71 in FIGURE 2, the dielectric layer 61 of Figure 5 has the same thickness as the dielectric layer 61 in FIGURE 2, the conductive strips 21 and 31 have the same widths and thicknesses as the strips 21 and 31 in FIGURE 2, and the space or gap between the conductive strips 21 and 31 in FIGURE 5 is the same as in FIGURE 2. Further, the coupler 130 operates in substantially the same manner as the coupler 10 of FIGURE 2, with similar performance characteristics.

FIGURE 6 is a diagrammatic fragmentary sectional view of a coupler 160 which is an alternative embodiment of the coupler 130 of FIGURE 5. The coupler 160 includes a portion which is structurally identical to the coupler 130 shown in FIGURE 5. The coupler 160 also has some additional structure. The additional structure includes a second dielectric layer 162 which is provided over the conductive strips 21 and 31 and over the dielectric layer

61, and also includes a further shield 164 which is provided on top of the dielectric layer 162. The dielectric layer 162 and the shield 164 are each formed using thick film techniques of a type known in the art.

The dielectric layer 162 in FIGURE 6 has the same thickness as the dielectric layer 61, but could alternatively have a different thickness which is compatible with formation of the dielectric layer 162 using thick film techniques. The dielectric layer 162 in FIGURE 6 is made from the same material as the dielectric layer 61, but could alternatively be made from some other suitable material. The shield 164 in FIGURE 6 has the same thickness, width and length as the shield 71 of FIGURE 6, and is aligned above the shield 71. Alternatively, however, the shield 164 could have a different thickness or a different length or width, within limits compatible with thick film techniques. The shield 164 in FIGURE 6 is made from the same electrically conductive material as the shield 71, but could alternatively be made from some other suitable material.

The provision of two shields 71 and 164 with the conductive strips 21 and 31 therebetween provides significantly enhanced coupling between the conductive strips 21 and 31, in comparison to the embodiment of FIGURE 5. Thus, providing a second shield is yet another design technique which can be used in a thick film coupler to set or tune the amount of coupling between the strips 21 and 31, thereby controlling the manner in which energy from the incident port is proportionally split between the direct port and coupled port.

Due to the additional coupling effect provided by the presence of two shields 71 and 164, it would also be

possible to increase the thicknesses of both dielectric layers 61 and 162, while maintaining a suitable degree of coupling between the strips 21 and 31. The thicker dielectric layers would serve to reduce the possibility of a pinhole short extending from either shield 71 or 164 to either strip 21 or 31.

FIGURE 7 is a diagrammatic fragmentary top view similar to FIGURE 1, but showing a coupler 210 which is an alternative embodiment of the coupler 10 of FIGURE 1. The coupler 210 of FIGURE 7 is effectively identical to the coupler 10 of FIGURE 1, except for differences which are discussed below.

The coupler 210 includes an electrically conductive section 216, with respective integral portions that include the strip 21, the incident port 22 with terminal 41, and the direct port 23 with terminal 42. The conductive section 216 differs from the conductive section 16 of FIGURE 1 primarily in that the direct port 23 extends away from the right end of the strip 21 approximately in the transverse direction 37 rather than in the transverse direction 36.

The coupler 210 also includes a further electrically conductive section 217, with respective integral portions that include the conductive strip 31, and the coupled port 32 with terminal 43. The conductive section 217 of FIGURE 7 differs from the conductive section 17 of FIGURE 1 primarily in that the conductive section 217 ends at the right end of the strip 31, whereas the conductive section 17 in FIGURE 1 has the isolated port 33 connected directly and integrally to the right end of the strip 31. In the coupler 210 of FIGURE 7, the isolated port 33 with terminal 44 is provided on the

substrate 12 in the form of a further electrically conductive section 218 of approximately square shape, the isolated port 33 being spaced approximately in the transverse direction 36 from the right end of the conductive strip 31.

The coupler 210 includes still another electrically conductive section 219. The conductive section 219 is provided on top of the dielectric layer 61, rather than between the substrate 12 and the dielectric layer 61, and can be formed at the same time as the shield 71. The conductive section 219 has one end disposed over the right end of the strip 31, and its other end disposed over the inner end of the isolated port 33. An electrically conductive via 226 extends vertically through the dielectric layer 61, and electrically couples the right end of the strip 31 to the end of the conductive section 219 disposed above it. A further electrically conductive via 227 extends vertically through the dielectric layer 61, and electrically couples the opposite end of the conductive section 219 to the inner end of the isolated port 33. The conductive section 219 extends approximately in the transverse direction 36, from the via 226 to the via 227.

The conductive sections 216-219 and the vias 226-227 are each formed using thick film techniques of a known type. The conductive sections 216-219 are each made of gold, and each have a thickness of about 300 microns. Alternatively, however, they could be made of some other suitable conductive material, and/or could have some other suitable thickness compatible with formation by thick film techniques. The vias 226-227 are made from

gold, but could alternatively be made from some other suitable material.

A significant difference between the coupler 210 of FIGURE 7 and the coupler 10 of FIGURE 1 is that the locations of the direct and isolated ports 23 and 33 have effectively been swapped. As a result, in FIGURE 7, the direct port 23 and the coupled port 32 are both on the same side of the coupler 210. This facilitates use of the coupler 210 with a category of circuits known as balanced circuits, examples of which are a balanced filter, a balanced amplifier, a balanced phase shifter, and a balanced attenuator. Aside from the fact that the positions of the direct and isolated ports are swapped, the coupler 210 operates in substantially the same manner as described above for the coupler 10, and provides comparable performance.

The present invention provides a number of technical advantages. One such technical advantage results from the provision of a hybrid coupler which is implemented using low-cost thick film technology, while providing a suitable degree of coupling. A related advantage relates to the use of a floating conductive shield in the region of the coupled structure, with a dielectric layer between the shield and the coupling structure. The shield significantly increases the degree of coupling, thereby permitting a gap between the coupled structure to be sufficiently large to permit implementation by thick film processing.

Still another advantage is that the coupler design tolerates a fair degree of manufacturing variations without exhibiting a significant variation in performance characteristics. A related advantage is that the coupler

provides broadband performance, and can be manufactured with high yields at low cost using thick film techniques.

Although selected embodiments have been illustrated and described in detail, it will be understood that various substitutions and alterations are possible without departing from the spirit and scope of the present invention, as defined by the following claims.

WHAT IS CLAIMED IS:

1. An apparatus comprising a coupler which includes:

a thick film dielectric layer having first and second sides;

a thick film first strip made of an electrically conductive material and disposed on said first side of said dielectric layer;

a thick film second strip made of an electrically conductive material and disposed on said first side of said dielectric layer, said first and second strips extending approximately parallel to each other; and

a thick film shield made of an electrically conductive material and disposed on said second side of said dielectric layer in alignment with said first and second strips.

2. An apparatus according to Claim 1, including a substrate disposed adjacent said first side of said dielectric layer, said first and second strips being disposed between said substrate and said dielectric layer.

3. An apparatus according to Claim 1, including a substrate disposed adjacent said second side of said dielectric layer, said shield being disposed between said substrate and said dielectric layer.

4. An apparatus according to Claim 3, including:  
a thick film further dielectric layer, said first and second strips being disposed between said dielectric layers; and

a thick film further shield disposed on a side of said further dielectric layer opposite from said substrate and in alignment with said first and second strips.

5. An apparatus according to Claim 1, wherein said shield has a width which is approximately equal to a distance between outer edges of said first and second strips.

6. An apparatus according to Claim 1, wherein said shield has a width which is greater than a distance between outer edges of said first and second strips.

7. An apparatus according to Claim 1, wherein said shield has a width which is less than a distance between outer edges of said first and second strips.

8. An apparatus according to Claim 1,  
wherein said first and second strips each have first and second ends, said first ends of said strips being adjacent and said second ends of said strips being adjacent; and

including thick film first, second, third and fourth port portions which are made of an electrically conductive material and which are disposed on said first side of said dielectric layer, said first and second port portions being respectively electrically coupled to said first and second ends of said first strip, and said third and fourth port portions being respectively electrically coupled to said first and second ends of said second strip.

9. An apparatus according to Claim 8,  
wherein said first and second port portions and said  
first strip are respective integral portions of a single  
conductive part;

wherein said third and fourth port portions and said  
second strip are respective integral portions of a single  
conductive part;

wherein said first and second port portions each  
extend away from said ends of said first strip and away  
from said second strip approximately in a first  
transverse direction; and

wherein said third and fourth port portions each  
extend away from said ends of said second strip  
approximately in a second transverse direction opposite  
said first transverse direction.

10. An apparatus according to Claim 1,  
wherein said first and second strips each have first and  
second ends, said first ends of said strips being  
adjacent and said second ends of said strips being  
adjacent;

including thick film first, second, third and fourth  
port portions which are made of an electrically  
conductive material and which are disposed on said first  
side of said dielectric layer, said first and second port  
portions being respectively electrically coupled to said  
first and second ends of said first strip, and said third  
port portion being electrically coupled to said first end  
of said second strip;

including a further portion which is made of an  
electrically conductive material, which is disposed on

said second side of said dielectric layer, and which has first and second ends; and

including electrically conductive first and second vias which extend through said dielectric layer at spaced locations, said first via electrically coupling said first end of said further portion to said fourth port portion, and said second via electrically coupling said second end of said further portion to said second end of said second strip.

11. An apparatus according to Claim 10,  
wherein said first and second port portions and said first strip are respective integral portions of a single conductive part;

wherein said third port portion and said second strip are respective integral portions of a single conductive part;

wherein said first port portion extends away from said first end of said first strip and away from said second strip approximately in a first transverse direction;

wherein said second port portion extends away from said second end of said first strip approximately in a second transverse direction opposite said first transverse direction;

wherein said third port portion extends away from said first end of said second strip approximately in said second transverse direction; and

wherein said further portion extends away from said second via approximately in said first transverse direction.

12. A method of making a coupler, comprising the steps of:

forming a dielectric layer using a thick film technique, said dielectric layer having first and second sides;

forming a first strip which is electrically conductive using a thick film technique, said first strip being disposed on said first side of said dielectric layer;

forming a second strip which is electrically conductive using a thick film technique, said second strip being disposed on said first side of said dielectric layer, and said first and second strips extending approximately parallel to each other; and

forming a shield which is electrically conductive using a thick film technique, said shield being disposed on said second side of said dielectric layer in alignment with said first and second strips.

13. A method according to Claim 12, including the step of providing a substrate; wherein said steps of forming said first and second strips includes the step of forming said strips on said substrate;

wherein said step of forming said dielectric layer includes the step of forming said dielectric layer over said substrate and said strips; and

wherein said step of forming said shield includes the step of forming said shield over said dielectric layer.

14. A method according to Claim 12,  
including the step of providing a substrate;  
wherein said step of forming said shield includes  
the step of forming said shield on said substrate;  
wherein said step of forming said dielectric layer  
includes the step of forming said dielectric layer over  
said substrate and said shield; and  
wherein said steps of forming said first and second  
strips includes the step of forming said strips over said  
dielectric layer.

15. A method according to Claim 14,  
including the step of forming a further dielectric  
layer using a thick film technique so that said first and  
second strips are disposed between said dielectric  
layers; and  
including the step of forming a further shield using  
a thick film technique, said further shield being  
disposed on a side of said further dielectric layer  
opposite from said substrate and in alignment with said  
first and second strips.

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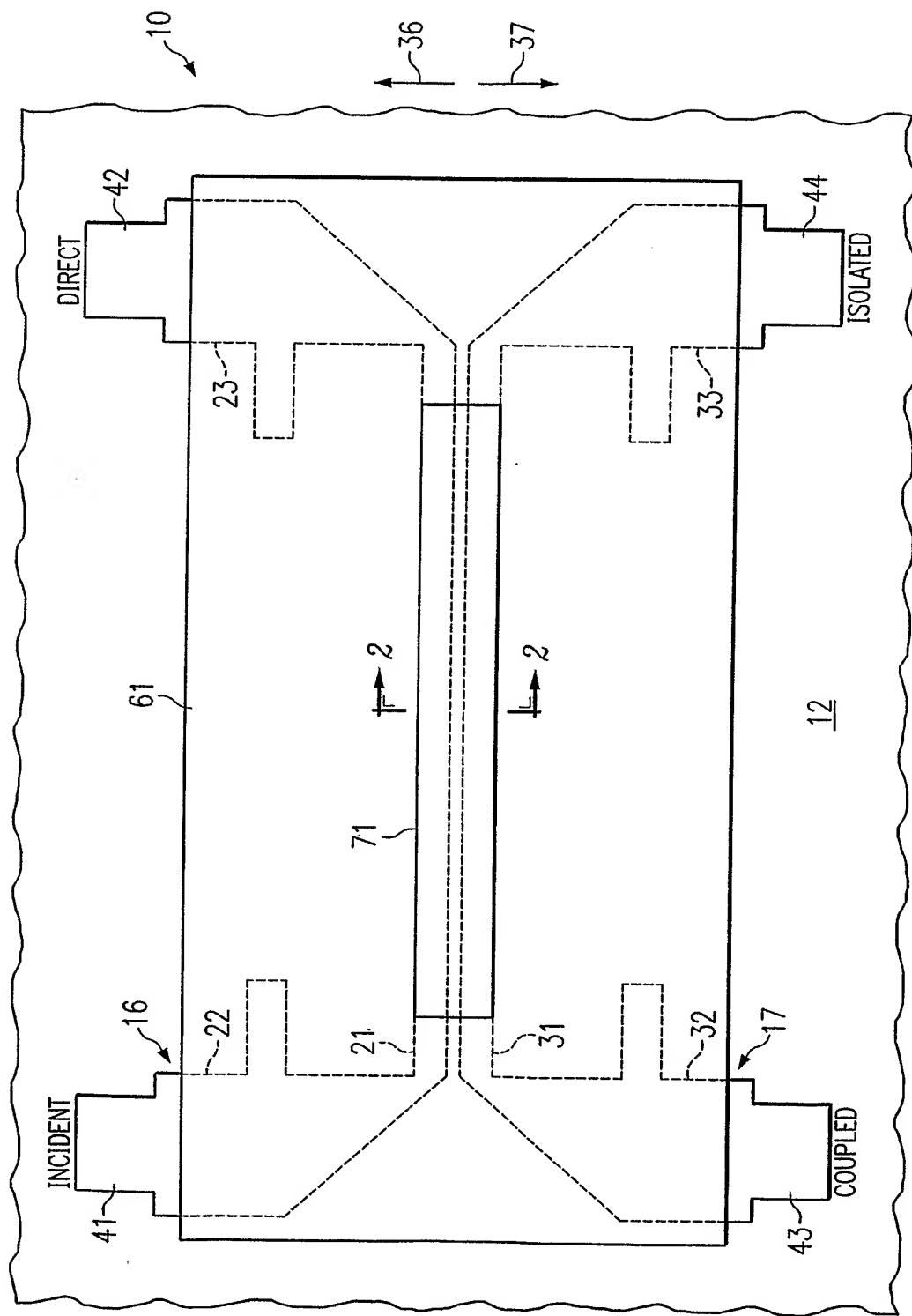


FIG. 1

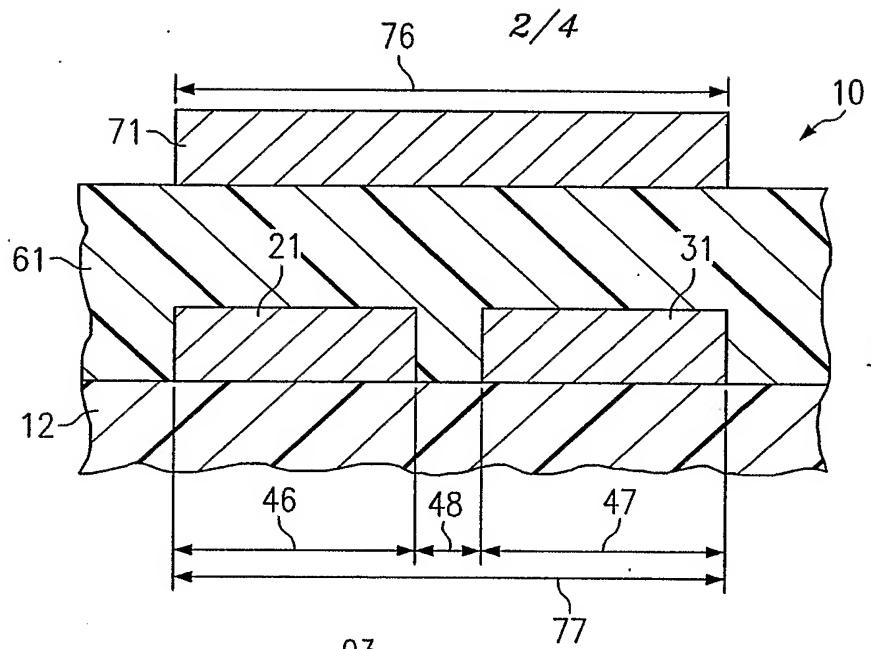


FIG. 2

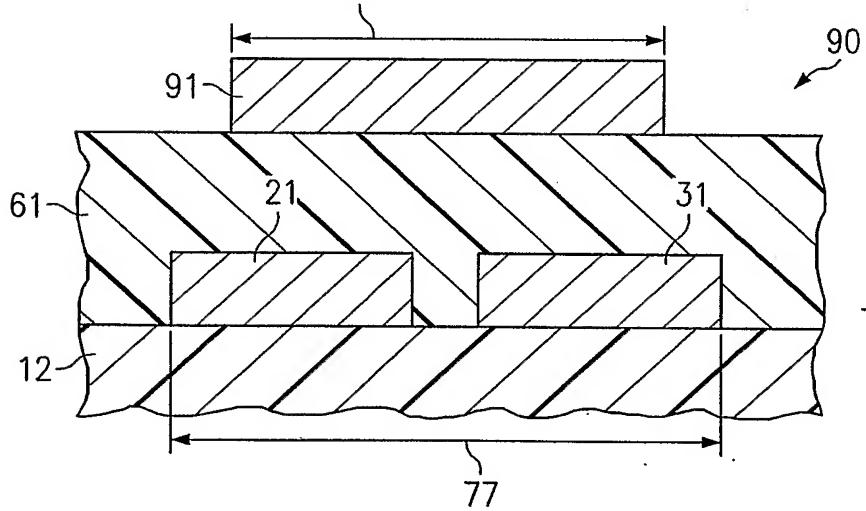


FIG. 3

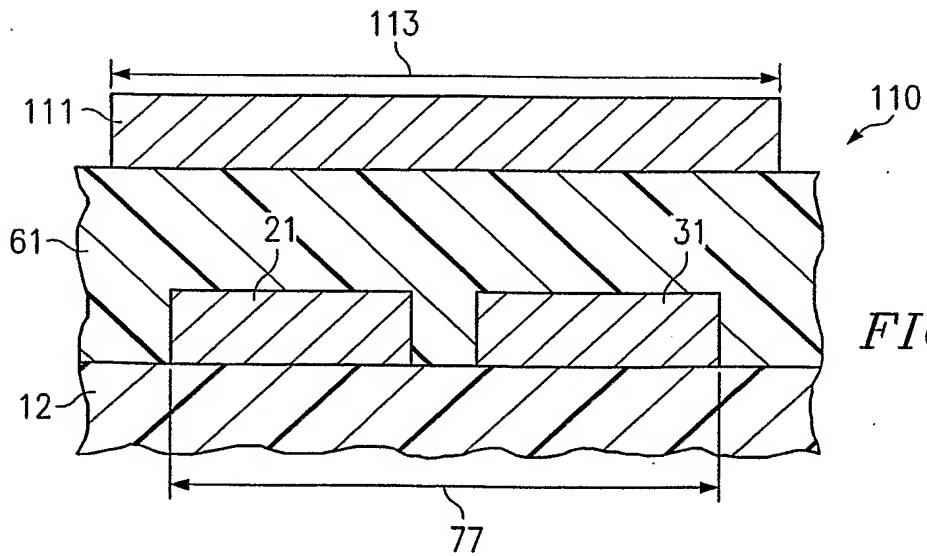


FIG. 4

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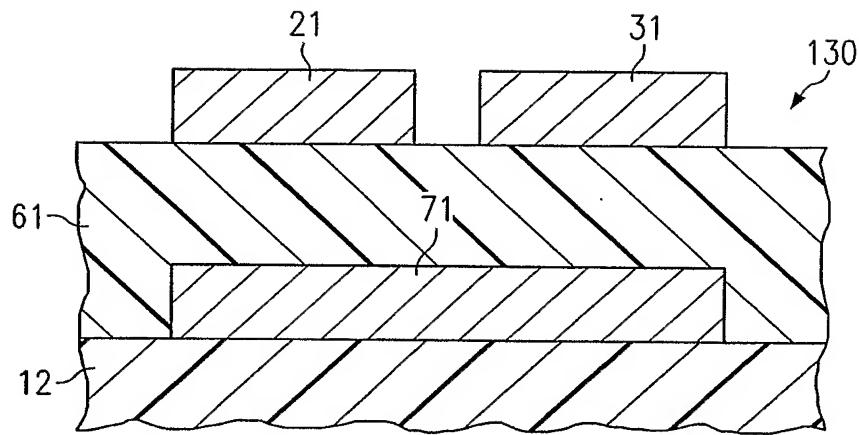


FIG. 5

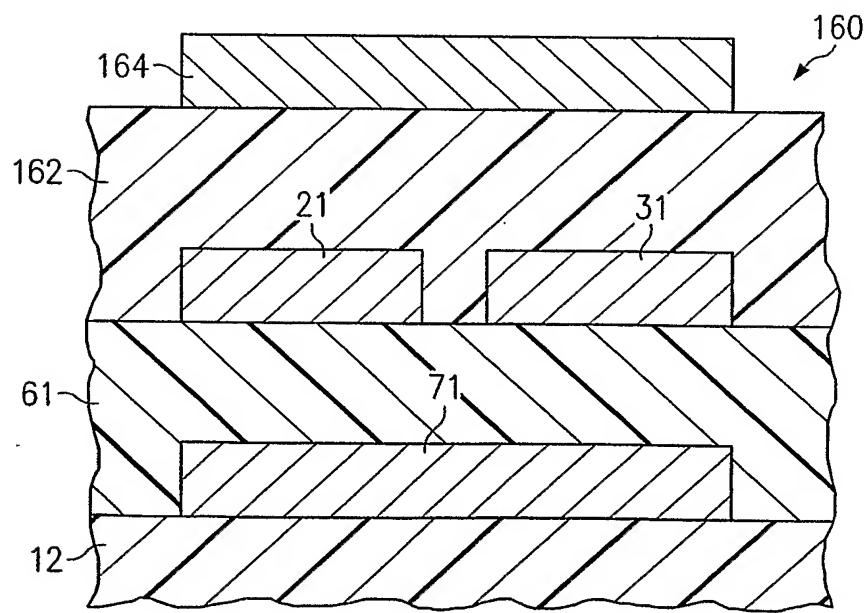
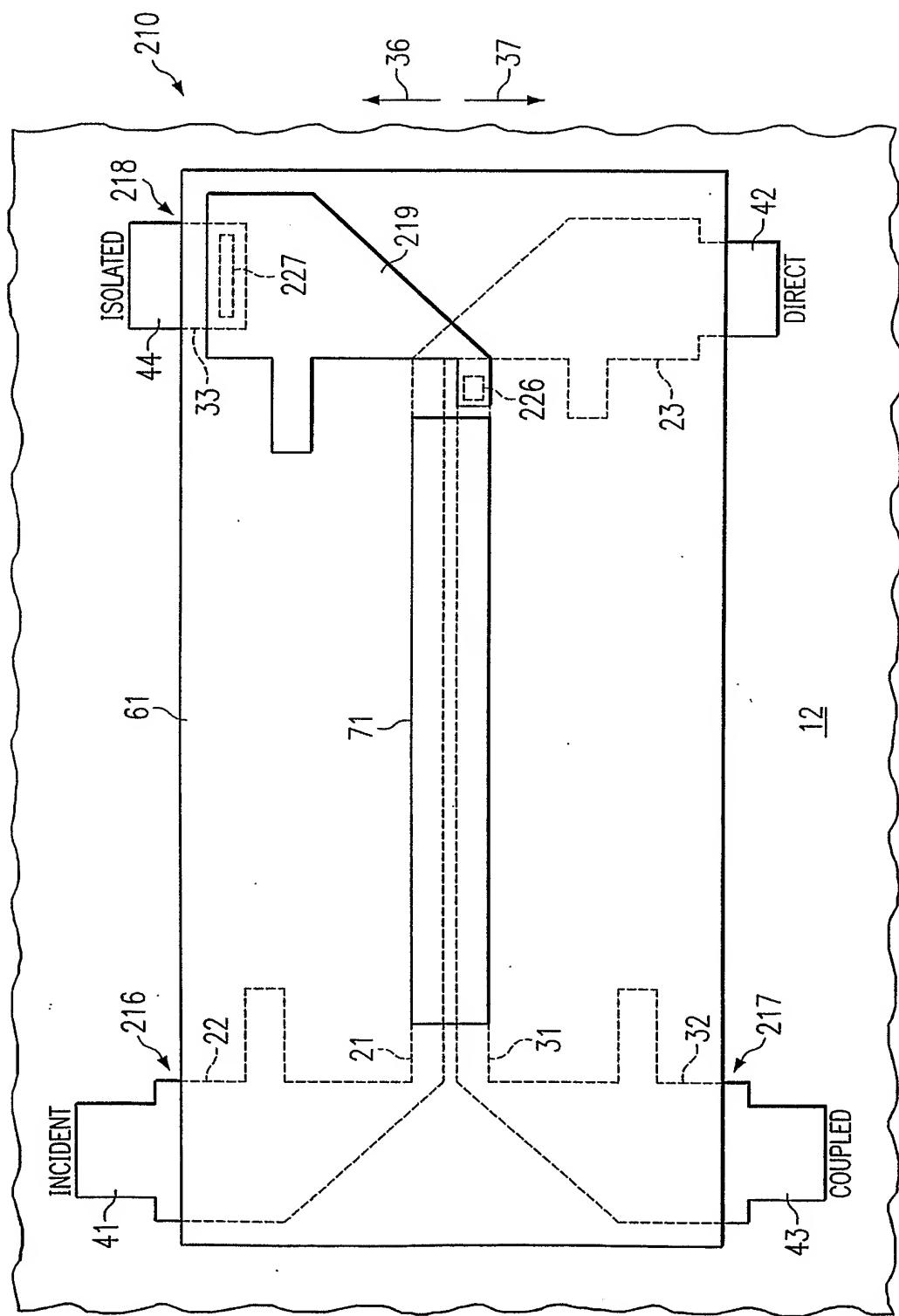


FIG. 6

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## INTERNATIONAL SEARCH REPORT

PCT/US 03/03841

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H01P5/18

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H01P H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, INSPEC

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 198 37 025 A (ROHDE & SCHWARZ) 17 February 2000 (2000-02-17) column 1, line 25 - line 48; figures 1,3	1,5-9
A	---	12,13
A	US 3 512 110 A (CLAR PHILIP L) 12 May 1970 (1970-05-12)  column 2, line 47 -column 3, line 69; figures 1,2	1,2,5, 7-9,12, 13
A	US 5 008 639 A (PAVIO ANTHONY M) 16 April 1991 (1991-04-16) column 2, line 43 -column 4, line 47 ----	1-3,5,6, 8,12-14
	-/-	

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

14 May 2003

Date of mailing of the international search report

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 013, no. 114 (E-730), 20 March 1989 (1989-03-20) & JP 63 286006 A (TOKYO KEIKI CO LTD), 22 November 1988 (1988-11-22) abstract --- US 4 288 761 A (HOPFER SAMUEL) 8 September 1981 (1981-09-08) column 1, line 67 -column 2, line 48; claim 1; figures 1-3 ---	1,2,5,6, 8,12,13  1-6,8, 12-15
A	WO 98 12769 A (RF PRIME CORP) 26 March 1998 (1998-03-26) abstract; figure 4 -----	1,8,10

## INTERNATIONAL SEARCH REPORT

PCT/US 03/03841

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
DE 19837025	A	17-02-2000	DE	19837025 A1		17-02-2000
US 3512110	A	12-05-1970	NONE			
US 5008639	A	16-04-1991	NONE			
JP 63286006	A	22-11-1988	NONE			
US 4288761	A	08-09-1981	NONE			
WO 9812769	A	26-03-1998	US AU DE DE EP JP JP KR WO	5745017 A 4482797 A 69709878 D1 69709878 T2 0927434 A1 3262173 B2 2000516787 T 2000036223 A 9812769 A1		28-04-1998 14-04-1998 28-02-2002 29-08-2002 07-07-1999 04-03-2002 12-12-2000 26-06-2000 26-03-1998